Week 3: Road Asset Management

Day 1 - Monday 10 June 2002

Road Asset Management Principles

CONTENTS

Road Asset Management ................................................................................................... 1
  Introduction .................................................................................................................. 1
  Asset management planning ....................................................................................... 1
    Benefits of Asset Planning ..................................................................................... 2
  Asset Valuation ........................................................................................................... 3
  Management Levels .................................................................................................... 3
    Planning ..................................................................................................................... 3
    Programming (Tactical planning) ............................................................................ 3
    Preparation .............................................................................................................. 4
    Operations ............................................................................................................... 4
  Road Asset Management Systems ............................................................................ 4
    Management Information ........................................................................................ 5
    Decision Support ..................................................................................................... 5
    Database Management System ............................................................................... 9
    Data Collection ....................................................................................................... 9
  Sustainability of Road Management Systems .......................................................... 11
  Conclusions .............................................................................................................. 11
  Acknowledgements ................................................................................................... 11
  Bibliography ............................................................................................................. 12

Road Asset Valuation ..................................................................................................... 13
  Introduction............................................................................................................... 13
  The balance sheet approach ...................................................................................... 13
  Assets ........................................................................................................................ 14
  Valuing road assets .................................................................................................. 14
  Valuation method ..................................................................................................... 15
  Condition and performance of the asset .................................................................. 18
  References ................................................................................................................. 19

Road Asset Management In New Zealand Strategies, Methods And Systems .......... 20
  New Zealand Roading Assets .................................................................................. 20
  Business Relationships ............................................................................................. 21
  Managing State Highways ......................................................................................... 22
    Key Objectives ....................................................................................................... 22
    Key performance indicators .................................................................................... 22
    Customer Research And Expectations ................................................................... 23
  Asset Management ................................................................................................... 24
    Aims Of Asset Management .................................................................................. 24
    The Objective Of The Asset Management Plan ................................................... 24
    Asset Management Complexities ......................................................................... 24
    Linkage Between The Asset Management Plan And Other Documents ............... 25
    Key Issues In The Management Of State Highways ............................................. 26
A Framework for Road Asset Management..............................................................................................35

- Introduction ..................................................................................................................................................35
- The management cycle .................................................................................................................................35
- Management functions ..................................................................................................................................37
- Dimensions of management ..........................................................................................................................39
  - Management processes for different functions ..........................................................................................39
- Road works ....................................................................................................................................................39
- Policy framework ..........................................................................................................................................41
- Information requirements ...............................................................................................................................44
- Methods of costing .........................................................................................................................................45
- Contracting out ..............................................................................................................................................46
- Specification of systems ..................................................................................................................................46
- The management framework ..........................................................................................................................46
- Acknowledgements ......................................................................................................................................47
- References ......................................................................................................................................................49

Examples of benefits from the application of policy frameworks ..............................................................50

- Routine maintenance ...................................................................................................................................50
- Gully emptying .............................................................................................................................................50
- Benefits of road inventory ..............................................................................................................................50
- Explicit policies .............................................................................................................................................51
- Reference: ......................................................................................................................................................51
Road Asset Management
Professor Henry Kerali, The University of Birmingham, UK.

Introduction

There are many definitions of infrastructure asset management. The following are particularly useful, and come from the New Zealand Infrastructure Asset Management Manual:

**Infrastructure Asset**
“Components of the built environment that provide services to the public such as the road system, water and waste water, electricity, gas supply, airports, railway, etc.”

**Infrastructure Asset Management**
“The combination of management, financial, economic, engineering and other practices applied to physical assets with the objective of providing the required level of service in the most effective manner”

**Basic Asset Management**
“Asset management which relies primarily on the use of an asset register, maintenance management systems, job/ resource management, inventory control, condition assessment and defined levels of service, in order to establish alternative options and long-term cash-flow predictions”

**Advanced Asset Management**
“Asset management which employs predictive modelling, risk management and optimised renewal decision making techniques to establish asset lifecycle options and related long-term cash-flow predictions”

Ultimately, the aim is to provide the required level of service at a cost that can be sustained, and in doing so to optimise the utilisation of assets. The key elements are that cost-effective and sustainable management practices are used to deliver a defined level of service using a ‘life cycle’ approach. A significant component of an asset management plan is a long-term cash-flow projection for activities.

**Asset management planning**

Asset management planning is an approach that is centred on placing a monetary value on the infrastructure being managed. Policies are then framed in terms of maintaining or enhancing the capital value of the asset, or allowing the value to decline. The effect of policies is therefore judged in terms of the impact they have on asset value. The approach combines management, financial, economic, engineering and other practices when applied to physical assets. It has the objective of providing the required level of service in the most cost-effective manner. It requires the use of a multi-disciplinary approach to management to develop and implement programmes for asset creation, operation, maintenance, renewal and disposal, over the life cycle of the asset. Performance monitoring is also needed to ensure that the desired levels of service and other operational objectives are achieved at optimum cost (see Figure 1 below).

In developing long-term planning projections, it is essential to understand the influence of short-term strategies on long-term outcomes, which although not immediately manifest may substantially distort strategic planning. This is particularly relevant for infrastructure services, where the public are ultimately liable for any widespread service failure resulting from persistent under investment. A common example of this are the road networks in many developing countries where complete rehabilitation or reconstruction is required to restore a large percentage of the road network to acceptable service levels.
Road asset management offers a discipline for integrating asset data in a way that facilitates its use for decision-making. It provides a framework for managing road networks using a long-term perspective, rather than the relatively short-term view currently adopted by many highway authorities. These all contribute to improving the ability to deliver services in the long term, which was one of the catalysts for the implementation of modern asset management systems. For example, the New Zealand Auditor General in 1993 noted that:

“...no assurance could be given that local governments financial position was secure in the long-term for two reasons:
1. the lack of knowledge on the condition of major assets,
2. the absence of strategic planning for service requirements in the medium to long-term”

Benefits of Asset Planning

Key benefits to organisations that adopt formal asset management systems and practices include:

- Improved understanding of service level options and requirements
- Minimum life cycle (long term) costs for an agreed level of service are identified
- Better understanding and forecasting of asset-related management options and costs
- Managed risk of asset failure
- Improved decision making based on costs and benefits of alternatives
- Clear justification for forward works programmes and funding requirements
- Improved accountability over the use of public resources
- Improved customer satisfaction and organisation image

Asset management planning enables asset owners to demonstrate to their customers and other stakeholders that services are being delivered in the most effective manner. It also provides a basis for evaluating complex service price/quality relationships in consultation with customers.
Asset Valuation

It is common nowadays for the value of a road network to be expressed in monetary terms. This concept is readily understood by wide range of decision-makers at all levels in the administrative hierarchy. The basic concept assumes that the current asset value of any road network can be estimated in monetary terms with reasonable accuracy at a particular point in time, in the same manner as the balance sheet of a company. Lack of maintenance will result in the deterioration of the network by physical attrition due to the effects of climate and traffic, which implies a continuous decrease in its asset value. Investment in the rehabilitation of roads, or the addition of completely new roads, implies an increase in the asset value of the network.

Asset valuation requires that assets are identified properly and recorded, taking into account the following:
- Components of the system need to be disaggregated into manageable units for maintenance purposes; often the level of disaggregation will be that at which components can be replaced.
- Sufficient information must be obtained to enable an assessment of the nature of the component, such as its dimensions and materials, and its replacement cost, age and remaining life.
- Components of the infrastructure asset should be recorded using a system that is regularly updated and reconciled to accounting records.

Road network assets can generally be valued in two ways; Optimised Depreciated Replacement Cost (ORDC), or the Renewals Accounting approach. The ODRC approach is based on the assumption that asset components making up the network can be replaced by modern equivalents. The optimisation process then reduces the replacement cost in steps to take account of surplus assets, obsolescence, over design, and any need for re-design or re-configuration.

Management Levels

When considering road asset management, the management process should be viewed in terms of the following functions: Planning, Programming (or Tactical Planning), Preparation, and Operations.

Planning

This involves an analysis of the road system as a whole, typically requiring the preparation of long term, or strategic planning estimates of expenditure for road development and preservation under various budgetary and economic scenarios. Predictions may be made of expenditure under selected budget heads, and forecasts of highway conditions in terms of key indicators, under a variety of funding levels. The physical highway system is usually characterised at the planning stage by lengths of road, or percentages of the network, in various categories defined by parameters such as road class or hierarchy, traffic flow/capacity, pavement and physical condition. The results of the planning exercise are of most interest to senior policy makers in the road sector, both political and professional. Work will often be undertaken by a planning or economics unit within a road agency. Typical outputs include:
- Projected annual capital and recurrent budget requirements to meet given standards for a user-defined future period.
- Projected pavement conditions resulting from the application of pre-defined annual budgets for a user-defined future period
- Projected highway authority costs and user costs for pre-defined standards, or annual budgets, for a user-defined future period
- Incremental NPV of adopting one set of standards compared with another, or of adopting one particular stream of annual budgets compared with another

Programming (Tactical planning)

This involves the preparation, under budget constraints, of multi-year road works and expenditure programmes in which those sections of the network likely to require maintenance, improvement, or new construction, are identified in a tactical planning exercise. The programming activity produces estimates of expenditure, under different budget heads, for different treatment types and for different years for each road section. Budgets are typically constrained, and a key aspect of programming is to prioritise works to find the best value for money in the case of a constrained budget. Typical applications are the preparation of a budget for an annual or rolling multi-year work programme for a road network, or sub-network.
Programming activities are normally undertaken by managerial-level professionals within a road agency, perhaps in a planning or a maintenance department. Typical outputs include:

- List of sections, showing recommended treatments and costs that can be funded in the budget year under pre-defined capital and recurrent budget constraint, in both priority and section order
- List of user-selected sections showing conditions and recommended treatments, in section order
- List of user-selected sections showing traffic, axle loading and user costs, in section order
- Projected rolling programme of work over a multi-year period

**Preparation**

This is the short-term planning stage where road schemes are packaged for implementation. At this stage, designs are refined and prepared in more detail; bills of quantities and detailed costing are made, together with work instructions and contracts. Typical preparation activities are: the detailed design of an overlay scheme; the detailed design of major works, such as a junction or alignment improvement, lane addition, etc. For these activities, budgets will normally already have been approved. Preparation activities are normally undertaken by relatively junior professional staff and technicians within a road agency, and by contracts and procurement staff. The main outcome are:

- Project formulation (produced interactively)
- Works order for project, including bill of quantities

**Operations**

These activities cover the on-going operation of a road agency. Decisions about the management of operations are made typically on a daily or weekly basis, including the scheduling of work to be carried out, monitoring in terms of labour, equipment and materials, the recording of work completed, and the use of this information for monitoring and control. Activities are normally focused on individual road sections with measurements often being made at a relatively detailed level. The tasks are normally managed by sub-professional staff, including works supervisors, technicians, clerks of works, and others. The key outcomes are:

- Performance standards for works, based on defined activities, plant and equipment costing, materials cost rates, and labour schedule and rates
- Work instruction/accomplishment
- Weekly labour time summary by person and budget head
- Weekly cost summary by activity and budget head, with totals
- Annual cost summary by section of highway, activity and budget head, with totals

**Road Asset Management Systems**

According to the Organisation for Economic Cooperation and Development (OECD), a sustainable road asset management system should include:

- Data collection methods that are affordable, appropriate and provide relevant information;
- Road information management system (or database management system) that is flexible and capable of producing both standard and ad hoc reports;
- A decision support system that can be used to investigate the consequences of various management decisions and strategies; and
- Adequate management information that are practical and pertinent to the needs of road organisations.

The relationship between the above components of a road management system is illustrated in Figure 2. Although the figure shows a logical flow of information starting with data collection through to management information, the actual process of implementing road management systems should begin with an assessment of the management information that is required by a road organisation. This should then be followed by the selection of the decision support system that will produce the required management information. The selection of an appropriate database management system should ideally ensure that this component will be compatible with the decision support system. Finally, the data required to provide the management information should be determined after all of the other components have been selected.
Management Information

The starting point in determining management information is that it must be relevant to the decision-making process at various levels within a road management organisation. Most organisations are structured into several layers of management responsibility starting with the chief executive or chief engineer at the top, down to the technical staff who are responsible for day-to-day tasks (e.g. works supervisors, technicians, junior engineers, etc.) A decision needs to be made regarding what levels of management within the organisation will require information from the road management system. This must be accompanied by exact definitions of the types, contents and formats of the management information required at each level.

In general, the management information may be classed into 3 groups:

- Performance indicators – information that can be used by the road organisation and by the public to measure how well the road network is managed. Such information includes predicted network performance trends, average travel speeds and average travel costs over a number of years.
- Operational statistics – information of a quantitative nature that is used mainly within a road organisation to assess budget needs, to measure annual achievements and to make judgements on the effectiveness and efficiency within the organisation.
- Decision criteria – information utilised by middle ranking management and technical professionals to make decision about annual work programmes and to select between project alternatives. These include prioritised lists of road projects and/or the economic indicators of project viability.

Decision Support

The purpose of a decision support tool is to provide the key management information that will assist senior policy makers and managers within the road organisation in the decision-making process. The primary role of the decision-support tool is to transform the data collected into meaningful information for the different management levels within an organisation. This will often require use of models, rules, knowledge-bases and other data processing techniques. It is essential that whatever data processing techniques are applied, they must be open (i.e. not a black-box) and be based on well-published research, procedures, or standards, that is well understood by both the management and technical staff within the road organisation. The transparency of analysis will determine the degree to which the road organisation will trust and believe in the results produced by the decision-support system.

For purposes of road management, the decision-support tool should incorporate principles of life cycle cost analysis as this forms the framework for medium and long term planning. Consequently, the Highway Development and Management tool (HDM-4) is often seen as a good decision support tool that serves the needs of road management.

The HDM-4 analytical framework is based on the concept of pavement life cycle analysis. This is applied to predict the following over the life cycle of a road pavement, which is typically 15 to 40 years: Road...
deterioration, Roadwork effects, Road user effects, and Socio-Economic and Environmental effects. Once constructed, road pavements deteriorate as a consequence of several factors, most notably; Traffic loading, Environmental weathering, and Effect of inadequate drainage systems. The rate of pavement deterioration is directly affected by the standards of maintenance applied to repair defects on the pavement surface such as cracking, ravelling, potholes, etc., or to preserve the structural integrity of the pavement (for example, surface treatments, overlays, etc.), thereby permitting the road to carry traffic in accordance with its design function. The overall long-term condition of road pavements directly depends on the maintenance or improvement standards applied to the road. Figure 3 illustrates the predicted trend in pavement performance represented by the riding quality that is often measured in terms of the international roughness index (IRI). When a maintenance standard is defined, it imposes a limit to the level of deterioration that a pavement is permitted to attain. Consequently, in addition to the capital costs of road construction, the total costs that are incurred by road agencies will depend on the standards of maintenance and improvement applied to road networks. It is essential to note that the accuracy of the predicted pavement performance depends on the extent of calibration applied to adapt the default HDM-4 models to local conditions.

The impacts of the road condition, as well as the road design standards, on road users are measured in terms of road user costs, and other social and environmental effects. Road user costs comprise: Vehicle operation costs (fuel, tyres, oil, spare parts, vehicle depreciation, utilisation, etc.), Costs of travel time - for both passengers and cargo, and Costs to the economy of road accidents (i.e., loss of life, injury to road users, damage to vehicles and other roadside objects).

The social and environmental effects comprise vehicle emissions, energy consumption, traffic noise and other welfare benefits to the population served by the roads. Although the social and environmental effects of often difficult to quantify in monetary terms, they can be incorporated within the HDM-4 economic analyses if quantified exogenously. It should be noted that in HDM-4, road user effects can be calculated for both motorised transport (motorcycles, cars, buses, trucks, etc.) and non-motorised transport (bicycles, human powered tricycles, animal pulled carts, etc.). Figure 4 illustrates the impact of road condition (represented in terms of the IRI) on the costs of different modes of transport.

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**Figure 3. Concept of Life-cycle analysis in HDM-4**
Figure 4. Effect of Road Condition on Vehicle Operating Costs for Rolling Terrain

Road User Costs in HDM-4 are calculated by predicting physical quantities of resource consumption and then multiplying these quantities by the corresponding user specified unit costs. It is necessary to ensure that the vehicle resource quantities predicted are in keeping with the range of values observed in the area of application.

Economic benefits from road investments are then determined by comparing the total cost streams for various road works and construction alternatives against a base case (without project or do minimum) alternative, usually representing the minimum standard of routine maintenance. HDM-4 is designed to make comparative cost estimates and economic analyses of different investment options. It estimates the costs for a large number of alternatives year-by-year for a user-defined analysis period. All future costs are discounted to the specified base year. In order to make these comparisons, detailed specifications of investment programmes, design standards, and maintenance alternatives are needed, together with unit costs, projected traffic volumes, and environmental conditions.

The main advantage of incorporating a tool such as HDM-4 within a road management system is that it is based on a well-understood analytical framework with well-published relationships and modelling framework. The key role that HDM-4 would play within a road management system is therefore that of the decision support tool. As such, it is designed to be able to:

- Support all of the functions of Planning, Programming, Preparation and Policy research as described earlier.
- Predict future impacts of funding levels and management policies on the road network performance and on road users.
- Provide reliable predictions of the interactions between the environment, traffic loading, construction standards and maintenance standards on the performance of the road network.
- Assess the impacts of road management policies on the life cycle costs of road pavements.
- Provide a mechanism for investigating optimum investment alternatives in the roads sector.

Figure 5 illustrates some of the typical management information that can be produced by HDM-4.
Figure 5. Example presentations of HDM-4 management information output

<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>EXAMPLE OUTPUT</th>
</tr>
</thead>
<tbody>
<tr>
<td>To determine the long term funding needs to meet target riding quality standards for main roads.</td>
<td>![Chart showing average roughness over years with budget allocations]</td>
</tr>
<tr>
<td>PLANNING</td>
<td>Annual Budget</td>
</tr>
<tr>
<td></td>
<td>$10m</td>
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<td>$15m</td>
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<td>$20m/yr</td>
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<tr>
<td>To determine optimal funding allocations to sub networks</td>
<td>![Chart showing budget allocations over years]</td>
</tr>
<tr>
<td>PLANNING</td>
<td>Feeders Roads</td>
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<td>Secondary Roads</td>
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<tr>
<td></td>
<td>Primary Roads</td>
</tr>
<tr>
<td>To determine optimal budget allocations between budget heads</td>
<td>![Chart showing budget allocations over years]</td>
</tr>
<tr>
<td>PLANNING</td>
<td>Development</td>
</tr>
<tr>
<td></td>
<td>Improvement</td>
</tr>
<tr>
<td></td>
<td>Periodic</td>
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<tr>
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<td>Routine</td>
</tr>
<tr>
<td>To produce a multi year works program within specified annual budget limits</td>
<td>![Table of road work priorities]</td>
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<td>PROGRAMMING</td>
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<table>
<thead>
<tr>
<th>Priority Rank</th>
<th>Road Section</th>
<th>Length (km)</th>
<th>Province or District</th>
<th>Type of Road Work</th>
<th>Scheduled Year</th>
<th>Cost $m</th>
<th>Cumulative $m</th>
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<tr>
<td>1</td>
<td>N1-2</td>
<td>20.5</td>
<td>2</td>
<td>Resealing</td>
<td>2000</td>
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<td>2</td>
<td>N4-7</td>
<td>23.5</td>
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<td>10.9</td>
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<td>N2-5</td>
<td>12.5</td>
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<td>R312-1</td>
<td>30</td>
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<td>Widen 4 lane</td>
<td>2000</td>
<td>31.4</td>
<td>56.3</td>
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<td>5</td>
<td>R458-3</td>
<td>36.2</td>
<td>3</td>
<td>Overlay 60mm</td>
<td>2000</td>
<td>16.3</td>
<td>72.6</td>
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<td>1</td>
<td>N4-16</td>
<td>32.1</td>
<td>6</td>
<td>Reconstruct</td>
<td>2001</td>
<td>22.8</td>
<td>45.6</td>
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<td>2</td>
<td>R13-23</td>
<td>22.4</td>
<td>4</td>
<td>Overlay 40mm</td>
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<td>9.7</td>
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<td>3</td>
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<td>41.3</td>
<td>73.8</td>
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</tr>
<tr>
<td>1</td>
<td>N1-6</td>
<td>30.2</td>
<td>4</td>
<td>Resealing</td>
<td>2002</td>
<td>8.2</td>
<td>8.2</td>
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<td>2</td>
<td>N7-9</td>
<td>17.8</td>
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<td>Overlay 60mm</td>
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<td>9.2</td>
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<td>3</td>
<td>F2140-8</td>
<td>56.1</td>
<td>1</td>
<td>Reconstruct</td>
<td>2002</td>
<td>34.9</td>
<td>52.3</td>
</tr>
</tbody>
</table>
Database Management System

The database management system (DBMS) effectively forms the data repository that provides quick and easy access to data for purposes of preparing management information. Normally, the most efficient and flexible structure for a road management system is one that is modularised, with integration achieved through a common database. This modular structure should reflect the manual operation of the road management process when broken down into functions and tasks. Many proprietary systems lack this modularity and are only available as complete systems, with a resulting loss in flexibility and ability to match the physical management structure.

With modular software, the database forms the backbone of the management system. This comprises the network referencing system around which is built an inventory of the network, and provides the framework within which all information about, or associated with, the network is stored and retrieved. The DBMS software must be flexible enough to accommodate future changes and growth. Although such an integrated approach should be a long-term target, in the medium-term, most road management systems may only contain part of the complete system. In many cases, it will be appropriate for a road organisation to implement a subset of the complete system, then to add more features and functions as the capability within the organisation grows. This approach represents an ideal situation and does have long-term benefits. Different parts of the system can be developed independently, at different times depending on the resources available, using different software products. The main disadvantages are that considerations of the long-term may dictate short-term actions, with the result that the initial solution may be more expensive and complicated than a dedicated application.

Data Collection

The key aspect about data collection for road management is to only collect the amount of data that is required to provide the necessary management information. For purposes of road maintenance, it is necessary to ensure that the minimum data collected provides information on the road inventory, pavement condition (riding quality, surface distress, and pavement strength), and traffic characteristics. The cost of data acquisition can be very expensive, and will often be the most expensive aspect of implementing and operating a road management system. System operation, itself, is likely to cost between two and four per cent of the maintenance budget provision. As such, it is essential that appropriate data design are undertaken if cost-effective results are to be obtained. Consequently, data collection for road management will often include the data groups summarised in Tables 1.

As the management process moves from planning, through programming and preparation to operations, the amount of data detail required tends to increase progressively in intensity, but to reduce in the extent of its network coverage. This feature can be used to assist the data design process by combining the functional levels of road management with information quality levels (IQL). These provide a standardised definition of the level of detail of different data items, such that they are of a consistent accuracy for different functions.

The selection of data items to be collected must therefore satisfy the following criteria:
- Relevance
- Appropriateness
- Reliability
- Affordability

Data collected will depend on the particular management strategy used in the road administration. This, in turn, depends on the approach adopted by the administration for each of the four management functions. Typical strategies are summarised in Box 1.
Table 1. Information groups

<table>
<thead>
<tr>
<th>Data Group</th>
<th>Aspects</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road inventory</td>
<td>Network, Furniture, Environ</td>
<td>• Location, Geometry</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Appurtenances, Signs, Lights, Culverts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Terrain, Rainfall</td>
</tr>
<tr>
<td>Pavement</td>
<td>Structure Condition</td>
<td>• Layers, Materials</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Surface distress, Riding quality, Structural performance</td>
</tr>
<tr>
<td>Structures</td>
<td>Structures inventory, Structure condition</td>
<td>• Bridges, Retaining walls, Tunnels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Traffic damage, Failures, Weathering</td>
</tr>
<tr>
<td>Traffic</td>
<td>Volume, Loading, Accidents</td>
<td>• AADT, Traffic mix, 24-hour volumes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ESAL (E80)</td>
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<td></td>
<td></td>
<td>• Severities, Rates</td>
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<td>Finance</td>
<td>Costs, Budget, Revenue</td>
<td>• Unit costs, Out-turns</td>
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<td>• Limits, Ceilings, Allocations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Tolls, Fines, User charges</td>
</tr>
<tr>
<td>Activities</td>
<td>Projects, Interventions, Commitments</td>
<td>• Progress record, expenditure, time scales</td>
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<tr>
<td></td>
<td></td>
<td>• Standards, Work types, Work effects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Budgets, schedules</td>
</tr>
<tr>
<td>Resources</td>
<td>Personnel, Materials, Equipment</td>
<td>• Staff, grades, salaries,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Quantities, storage, unit costs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Outputs, consumption, unit costs</td>
</tr>
</tbody>
</table>

Box 1. Typical strategies for data collection

Strategy A
High-level condition data (typically IQL-IV) are collected across the whole network each year. This is used for planning and programming purposes. The programming exercise then collects more detailed data (typically IQL-III) on those sections where works are likely to be undertaken. More detailed data (typically IQL-II) are then collected on some of the sections for which designs are produced, or for which works are undertaken. As more detailed data are collected on any section, they replace that collected in the earlier phase, with the result that different sections in the database store data at different levels of detail.

Strategy B
Relatively detailed data (typically IQL-II/III) are collected across parts of the network on a rolling programme, perhaps with a cycle of three to five years. Each year, programming decisions are taken either using current data for individual sections, if available, or by projecting forward condition data from previous years. Thus all condition data tends to be stored at the same level of detail, although data collected as part of the works design or execution processes may also be stored.

Other strategies
Other combinations of the above are also used, including the following examples:

• Annual data can be collected on the primary road network, whereas a cycle of data collection may be used on roads lower in the hierarchy
• The cyclic approach can be used for the whole network, but collecting data at low levels of detail (IQL-III/IV)
• Cyclic collection methods can be used without projection of condition. Some administrations collect detailed data annually across the whole network, although this approach is unlikely to stand up to investigations of cost-effectiveness

All have different implications for the level of data detail stored in the database of the road management system.
Sustainability of Road Management Systems

In simple terms, to sustain is to support something and prevent it from collapse. However, the term sustainability has been used in different ways by various sectors. For example, USAID considers a development programme to be sustainable if it can still provide required benefits to the local community for a considerable duration after all external assistance has been withdrawn. In agricultural development, an output growth can never be considered sustainable unless it exceeds the population growth.

Sustainability in the road management context therefore means that there is strong will, commitment and resources within the organisation to maintain, operate and subsequently improve the road management system by using local resources and staff.

Consequently, the implementation of a sustainable road management system should consider:

- Existing institutional arrangements and any required changes;
- The relevance and need for management information produced;
- The capability of the agency to collect the required data and keep them current;
- Technical knowledge required to operate and subsequently improve the system if and when the need arises;
- Knowledge and computer skills available within the agency (if a computerised system is adopted);
- Staff training programmes in the area of pavement management.

Pavement management systems that have been introduced in many developing countries are often too complicated and too demanding to be sustainable. In determining the requirements of a road organisation it is therefore necessary to consider the capacity of the organisation in terms of financial and human resources required to operate the system. Consequently, to ensure sustainability, each component of the road management system has to be designed such that the organisation is able to maintain and operate the system using local resources at minimum cost. At the same time, the system should produce realistic and technically feasible management information within available resources. This includes the requirements for data collection, updates of the decision-support tool, and maintenance of the database management software.

Conclusions

This paper has presented a framework and specifications for the implementation of a sustainable road infrastructure asset management system by a road organisation, as well as a summary of the institutional reforms that are necessary to improve the efficiency and effectiveness of road management. The paper defines sustainability or road management systems as the long-term ability to operate and subsequently improve the road management system using local staff and resources. When implementing a road management system, it is important that a road organisation should consider the following:

- The proposed data collection scheme;
- Procurement of the required hardware and software;
- Necessary training of key staff responsible for operating the system;
- Acquisition of computer knowledge and skills required to maintain and upgrade the system.

The most critical parameters are human resource constraint and time required to collect the data. Underestimate of the time required to collect, input and validate the data into a road management system is often a common hindrance to sustainability. In general, for the sustainability of a road asset management system, road organisations should consider using simple but technically compatible methods in the development and implementation of the system. These methods are particularly recommended for developing countries that cannot afford expensive high-tech solutions.

Acknowledgements

Much of the material presented in this paper has been extracted from the publications listed in the bibliography. However, the additions and interpretations presented in this paper are those of the author and do not necessarily reflect those given in the bibliography.
Bibliography

15. TRL (2000). Guidelines for the implementation of road management systems, ORN 15. Overseas Centre, Transport Research Laboratory, Crowthorne, Berkshire, UK.
Road Asset Valuation
Source: Robinson, R. Prepared for the Senior Road Executives Programme, The University of Birmingham

Introduction

Roads as an asset
Some road administrations are approaching the issue or road management by treating roads as a capital asset. The aim under this approach is the conservation of the inherent asset value of the network expressed in monetary terms. This concept is readily understandable by wide range of decision-makers at all levels in the administrative hierarchy.

Assigning a monetary value
The basic concept assumes that the current asset value of any road network can be estimated in monetary terms with reasonable accuracy at a particular point in time, in the same manner as the balance sheet of a company. Lack of maintenance will result in the deterioration of the network by physical attrition due to the effects of climate and traffic, which implies a continuous decrease in its asset value. While investment in the rehabilitation of currently unusable roads, or the addition of completely new roads, implies an increase in the asset value of the network, this is likely to be more than counter-balanced by the losses incurred from non-maintenance of existing maintainable routes.

Basis for considering investments
Thus, the wisdom of any investment programme and, crucially, the balance between capital and recurrent expenditure, can be judged on whether or not it increases the net asset value of the network. Programmes, which result in a decrease in the asset value, simply cannot be regarded as ‘development’. Such would be the likely consequence of an over-emphasis on investment in construction relative to that in maintenance.

The balance sheet approach

Assets and liabilities
This requires the administration to value its assets and liabilities annually, and to pay interest on productive capital. A view of the assets and liabilities involved is given in Table 1.

Table 1. Assets and liabilities of a road administration

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed assets: the roads</td>
<td>Basic equity capital (productive)</td>
</tr>
<tr>
<td></td>
<td>• The main highway network</td>
</tr>
<tr>
<td></td>
<td>• Interest paid on this capital</td>
</tr>
<tr>
<td></td>
<td>• Capital introduced by government</td>
</tr>
<tr>
<td></td>
<td>• Note that capital will not be repaid</td>
</tr>
<tr>
<td>Materials and supplies</td>
<td>Other equity capital (unproductive)</td>
</tr>
<tr>
<td></td>
<td>• The ‘social’ road network</td>
</tr>
<tr>
<td></td>
<td>• Other investments done for ‘social’ reasons</td>
</tr>
<tr>
<td></td>
<td>• Note that no interest is paid on this capital</td>
</tr>
<tr>
<td></td>
<td>• (Aim is preservation of the network)</td>
</tr>
<tr>
<td>Plans</td>
<td>Reserves</td>
</tr>
<tr>
<td>Financial assets</td>
<td>Loans</td>
</tr>
<tr>
<td></td>
<td>• Loans to increase productive capital</td>
</tr>
<tr>
<td></td>
<td>• Interest and repayment</td>
</tr>
</tbody>
</table>

Source: adapted from Talvitie (1996)
Assets

Assets consist of the road network, buildings, materials and supplies, the plans and financial assets. Plans are considered as an asset to provide an incentive to management to improve the planning cycle and to eliminate the desire to produce plans for providing new roads just in case there is a political window to implement them.

Liabilities

When considering liabilities, the road network has been divided into two parts: the ‘economic’ network (productive equity capital) and the ‘social’ network (unproductive equity capital). Other liabilities include reserves, from ‘profits’, and loans that the administration may want to take to implement road projects quickly that have high rates of return. The government can, at its discretion, infuse either productive or unproductive capital to achieve goals other than those related directly to transport. The consequences of such allocations will have repercussions on the road administration because, unless there is increased revenue to match the cost increase necessary to manage these additional roads, then a loss will be incurred.

Requirements

A key feature of this approach is the requirement for a road administration to value the assets on an annual basis. This requires:

- Developing a method to value the road assets
- Developing procedures and processes to serve multiple governments (owners)
- Developing procedures for planning in the new administrative environment
- Identifying what kind of government oversight is necessary
- Developing an approach to how the private sector will be represented

Clearly, the operation of the road administration must also be subject to annual financial and technical audit.

Social roads

With some exceptions, the national road administration normally is responsible for the main road network. In this case, it is unlikely that it would be responsible for many ‘social’ roads valued as ‘unproductive capital’. However, applying an assets-based approach to other roads in the network poses difficulties of ‘balancing the books’ unless some kind of subsidy is introduced to cover the social liability requirements. These roads are typically the responsibility of the lower levels of government, including municipalities, counties, districts, etc.

Valuing road assets

Basis of valuation

Asset identification and recording

Asset valuation requires that assets are identified properly and recorded, taking into account the following:

- Components of the system need to be disaggregated into manageable units for maintenance purposes; often the level of disaggregation will be that at which components are replaced

- Sufficient information must be obtained to enable an assessment of the nature of the component, such as its dimensions and materials, and its replacement cost, age and remaining life

- Components of the infrastructure asset should be recorded using a system which is regularly updated and reconciled to accounting records

Categories of expenditure

All expenditure on infrastructure assets should fall into one of the categories shown in Box 1.
Box 1. Categories of expenditure

Operations
Expenditure that has no effect on asset condition but is necessary to keep the asset appropriately utilised. It includes costs of overheads, power, and the like.

Maintenance
Expenditure to cover the on-going day-to-day work required to keep the assets operating at required service levels. It includes repairs and minor replacements.

Renewal
Expenditure on significant work required to replace an existing asset, or restore it to its original size, condition or capacity.

Development
Expenditure on works which create new assets, or which upgrade or improve an existing asset beyond its original capacity or performance in response to changes in usage, customer expectations, or anticipated future need.

Disposal
Expenditure which includes any costs associated with the disposal of a decommissioned asset.

Source: National Asset Management Steering Committee 1996

Limitation of accounting methods
Current accounting practices do not provide specific consideration of the special characteristics of infrastructure assets, and generally treat them no differently to other assets. Difficulties that surround accounting for infrastructure assets relate largely to the measurement of the value itself, and to the reporting of changes in service potential in terms of depreciation and renewals. In some cases, valuation and accounting treatment is based largely on earnings potential. In other cases, the focus is on the provision of services and its quality, rather than on return on investment: the emphasis in this case is on how well the assets are managed and maintained for service. The long life and large investments in assets necessitates the development of asset management plans that forecast future deterioration, maintenance and enhancement needs. Depending on the valuation objective, different methods of valuation can be used. Normally, the aim of methods is to measure the change in service level from one accounting period to the next.

Valuation method
Assets can be valued in a number of ways. The relevant valuation method for roads is given in Table 2.

Depreciation approach to valuation
Depreciation accounting is based on the assumption that depreciation of the network equals the sum of the depreciation of all of the asset components making up the network. The method typically involves the following steps:

1. Identify the components making up the infrastructure asset
2. Calculate the depreciated replacement cost (DRC) of each component; DRC is the replacement cost of an existing asset after deducting an allowance for wear or consumption to reflect the remaining economic life of the asset
3. Calculate the remaining economic life (REL) of each component; REL is the time remaining until an asset ceases to provide service level or economic usefulness
4. Determine the loss of service potential by accumulating the DRC of each component over its REL, typically using straight line depreciation to give the same depreciation each year.

5. Debit this loss of service potential each year as depreciation expense.

The concept of straight line depreciation is illustrated in Figure 1.

<table>
<thead>
<tr>
<th>Feature/service area</th>
<th>Basis of valuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>Market value</td>
</tr>
<tr>
<td>Road formation and subgrade</td>
<td>Replacement cost</td>
</tr>
<tr>
<td>Road pavement</td>
<td>Depreciated replacement cost</td>
</tr>
<tr>
<td>Footways, footpaths and cycleways</td>
<td>Depreciated replacement cost</td>
</tr>
<tr>
<td>Bridges and structures</td>
<td>Depreciated replacement cost</td>
</tr>
<tr>
<td>Traffic facilities, signs and road furniture</td>
<td>Depreciated replacement cost</td>
</tr>
<tr>
<td>Buildings</td>
<td>Market value</td>
</tr>
<tr>
<td>Plant and equipment</td>
<td>Market value</td>
</tr>
<tr>
<td>Materials and supplies</td>
<td>Market value</td>
</tr>
<tr>
<td>Existing plans and designs</td>
<td>Replacement cost</td>
</tr>
<tr>
<td>Financial assets</td>
<td>Financial value</td>
</tr>
</tbody>
</table>

*Note:* The replacement cost of an asset may be calculated by using the prevailing market costs for provision of a similar asset in similar condition.

*Source:* National Asset Management Steering Committee 1996

![Figure 1 Depreciation approach to valuation](Source: National Asset Management Steering Committee 1996)
Renewals-based approach to valuation

Long-run cost approach
The renewals accounting approach recognises the network nature of the asset and the inter-dependence of its components. The method recognises that the planned renewal expenditures are rarely constant over time, so bases its approach on the long-run average of the estimated cost of asset renewals. These estimates are based on condition assessments and life cycle analysis.

Estimating loss of service potential
The change in the carrying value of the asset is related to the difference in the cumulative value of this rolling estimate and the cumulative value of actual expenditures. The accounting entity debits this amount each year as the depreciation expense, and credits the accumulated actual expenditure. The loss of service potential of the asset is based on the average of a rolling estimate of the renewal expenditure. In years when expenditure is less than the long run average, the asset value falls, and vice versa. If scheduled renewals do not take place, then there will be a permanent fall in the residual asset value.

Example
In the example in Figure 2, the average 20-year renewal expenditure is $60 000 per annum, although in reality it would probably change each year as the forecast horizon changes. This is the recorded loss in service potential each year and is recognised as an expense. The network carrying value at the beginning of the forecast period is $3 million. All renewals are carried out each year as planned and are capitalised. The annual fluctuations in asset service potential are illustrated below. It will be noted that, in the year 2000, the difference between actual and average long-run renewal ($30 000-$60 000) results in a $30 000 decrease in carrying value; whereas, in 2001, the difference ($150 000-$60 000) results in a $90 000 increase in the carrying value of the network.

![Figure 2 Renewals-based approach to valuation](Source: National Asset Management Steering Committee 1996)
Steps in the approach
The renewals-based approach typically involves the following steps:

1. The asset owner formally makes a decision to maintain specified assets at a defined level of service using the renewals-based approach

2. An asset management plan is prepared to provide reliable information on the timing, extent and cost of the renewal work required to maintain and restore the network’s defined service potential within the forecast period, normally at least 20 years

3. The loss of service potential of the asset is based on the average of a rolling estimate of this ‘renewal expenditure’; this amount is debited each year as a depreciation expense, and the actual expenditure is credited

All expenditure that increases the service potential of the network is classified either as:

- **Renewal**
  Restores and sustains the service potential of the whole network and which should be capitalised

- **Development**
  Adds to the service potential of the whole network and should be taken as capital investment

The cost of work classified as *maintenance* or *operations* is treated as an expense.

Comment on methods
The depreciation accounting approach is simpler to use than renewal accounting. However, there are questions about whether depreciation of network components is an appropriate measure of changes in the total system service potential. The method is also perceived as being backwards-looking, because it concentrates on past costs rather than future management of the asset.

Condition and performance of the asset

Performance curves
Methods of valuation need to take into account the condition and performance of the asset over time. *Condition* relates to the structural integrity of the asset. *Performance* relates to the capability of the asset to meet defined service criteria. A generic performance curve is shown in Figure 3 in terms of a condition rating and effective life. The details of the actual curve will depend on how the condition rating is defined and on the units of effective life.

Treatment and performance
In simple terms, it may be possible to link treatments to condition rating defined in this manner, as in Table 3, although in practice the treatment selection decision making process is likely to be much more complex (see, for example, Robinson and others 1998 Chapter 6).

<table>
<thead>
<tr>
<th>Condition Rating</th>
<th>Description</th>
<th>Works types needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Excellent</td>
<td>Cyclic maintenance</td>
</tr>
<tr>
<td>2</td>
<td>Good</td>
<td>Reactive maintenance</td>
</tr>
<tr>
<td>3</td>
<td>Fair</td>
<td>Preventive or resurfacing works</td>
</tr>
<tr>
<td>4</td>
<td>Poor</td>
<td>Structural overlay</td>
</tr>
<tr>
<td>5</td>
<td>Very poor</td>
<td>Pavement reconstruction</td>
</tr>
</tbody>
</table>
References


Road Asset Management In New Zealand Strategies, Methods And Systems

Presenter: Paul Hambleton (Original material developed by Graham Taylor and others)

Paul Hambleton is the Engineering Policy Manager in the Transit New Zealand Head Office. He has a primary responsibility for the development of Transit’s standards and specifications for state highways. Paul has worked in Indonesia for some ten years and has worked as a consultant on World Bank financed highway planning and quality control work. In earlier years Paul was employed by the MWD - Ministry of Works and Development in Wellington developing pavement maintenance quality assurance programmes as well as assisting The New Treasury with an initiatives to improve financial and asset management throughout the New Zealand public sector.

Note: Road Transportation is referred to colloquially in New Zealand as “Roading”

New Zealand Roading Assets

New Zealand is a highly developed, sparsely populated and commercially progressive nation. With this comes dependence on communications and on a substantial roading asset. The extent of the network is significant comprising a total of approximately 57,000 kilometres of sealed public road and a further 35,000 kilometres of unsealed road. Roading management is a challenge in New Zealand. We have a long narrow mountainous country of similar geographical area to England, but with 15 times less population at around 3.8 million.

The extent of associated assets is also significant and includes some 3,500 bridges, many tens of thousands of signs, delineation devices, culverts etc. The disposition of key assets is summarised in Table 1.

<table>
<thead>
<tr>
<th>Roads</th>
<th>Sealed km</th>
<th>Unsealed km</th>
<th>Total km</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Highway</td>
<td>10540</td>
<td>236</td>
<td>10776</td>
</tr>
<tr>
<td>Local Urban</td>
<td>15519</td>
<td>443</td>
<td>15962</td>
</tr>
<tr>
<td>Local Rural</td>
<td>30967</td>
<td>34541</td>
<td>65508</td>
</tr>
<tr>
<td>Total Length</td>
<td>57027</td>
<td>35048</td>
<td>92075</td>
</tr>
</tbody>
</table>

Table 1

<table>
<thead>
<tr>
<th>Bridges</th>
<th>Total Bridges</th>
<th>Total Length km</th>
<th>Single Laned</th>
<th>Timber</th>
</tr>
</thead>
<tbody>
<tr>
<td>3525</td>
<td>116</td>
<td>205</td>
<td>28</td>
<td></td>
</tr>
</tbody>
</table>

The period of significant development for infrastructural assets in New Zealand ended in the late 1960’s. Management attention is now focussed on preservation. In the current economic environment improvement and replacement programmes are subjected to rigorous economic scrutiny. Typically expenditure patterns applied to the $990 million per year roading budget allocate approximately 50% to maintenance, 47% to improvement and 3% to replacement.
With this expenditure pattern and focus on preservation there has been a notable growth trend of the asset management discipline within the roading engineering environment, and a growing focus on the development of refined asset management practices and business systems.

**Business Relationships**

The roading assets are managed by 75 road controlling Authorities. Transit manages the State Highway assets with the 74 Territorial Local Authorities (TLA’s) managing the balance. Transfund New Zealand manages the distribution of funds from the dedicated roading fund to these authorities based on an annual submission. This management structure is illustrated in the figure 2 below.

![Figure 2](image-url)

**Figure 2**

**Figure 3 – Business Agencies and Relationships**

<table>
<thead>
<tr>
<th>Agency</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Controlling Authority (Client)</td>
<td>• Statutory control</td>
</tr>
<tr>
<td></td>
<td>• Service acquisition (Consulting Services and Physical Works)</td>
</tr>
<tr>
<td></td>
<td>• Audit</td>
</tr>
<tr>
<td></td>
<td>• Principal to Consulting and Physical Works Contracts</td>
</tr>
<tr>
<td>Consultant</td>
<td>• Network Management Services</td>
</tr>
<tr>
<td></td>
<td>• Contract Supervision</td>
</tr>
<tr>
<td></td>
<td>• Quality Management</td>
</tr>
<tr>
<td>Contractor</td>
<td>• Physical Works</td>
</tr>
<tr>
<td></td>
<td>• Quality Control</td>
</tr>
</tbody>
</table>

Functions associated with the management of the asset can be categorised into three broad areas and in the current management environment separate autonomous bodies execute these.
Legislation requires that all Road Controlling Authorities remain autonomous from the Consulting and Contracting services. RCA’s now act only in the role of Client, acting as Principal to the Contracts for the provision of both Consultancy and Physical Works services.

Managing State Highways

Key Objectives

Transit’s key objectives for the state highway system are:

- To provide a consistent, safe and “forgiving” road environment with no surprises for road users
- To provide road users with realistic perceptions of danger
- To minimise journey times and vehicle operating costs
- To provide state highways for current and future road users, and plan for the future
- To provide an environment for pleasant travel
- To provide convenient facilities which cater for the needs and expectations of road users
- To minimise the environmental effects of highway maintenance and construction on road users generally

Key performance indicators

Key performance indicators allow Transit to monitor how effectively it is delivering on its key result areas. Transit’s preliminary KPI’s for efficiency and safety were developed in 1998 and are still in the developmental stage. Transit is also in the process of developing KPI’s to monitor how effectively it is delivering quality service to road users and also environmental mitigation, avoidance and remedy of road effects.

Indicators of efficiency:

- Geometric efficiency
- Roughness
- Bridge weight restrictions

Indicators of safety:

- Number and cost of crashes
- Compatibility with speed environment
- Sealed carriageway width
- Bridge width deficiencies
Customer Research And Expectations

Customer Satisfaction

To ensure Transit is continually in-step with its stakeholders and customers requires constant consultation. Typically this occurs through annual negotiation and consultation with the Ministry of Transport and Transfund regarding their respective agreements with Transit; consultation regarding National State Highway Strategy and regional SH Strategies; consultation on Transit’s Annual Plan; and finally through targeted consultation with road users.

In August 1997, Transit resolved to proceed with a programme of consultations with road users involving:

- Development and implementation of a State Highway Satisfaction Survey to identify satisfaction with the state highway network. The survey is to be treated biennially to measure trends (1000 road users in NZ, with the sample representative of the general population).
- Participation in the 1997/98 Austroads User Satisfaction Survey to benchmark how well Transit is perceived to be meeting road user needs compared to Australian road controlling agencies.
- Development and implementation of a heavy vehicle user satisfaction survey

Customer Preferences

Customer preferences as expressed in their perceived needs and expectations should influence the motivation to carry out work to ensure the effectiveness of the business. If the outputs of work on the network do not equate directly to those customers’ preferences the overall goal is not achieved.

To facilitate this process, surveys to ascertain customer preferences where possible:

- are structured to capture expectation that can be directly translated into intervention and performance standards.
- have attempted to cover all outputs of the intervention process such that prioritisation can be achieved
- are focussed on willingness to pay such that economic justification is taken into account.

Transit will continue to place a high priority on ascertaining customer preferences, recognising that these impact significantly on the focus of our business systems.

Customer expectations impact on, and are implemented through, two programmes:

- SH Replacement and Improvement Programme (Capital and renewals)
  Implementation of customer expectations through the capital programme is relatively straightforward in terms of business practices. Overtime, as customer preferences are identified and quantified through willingness to pay research, the economic evaluation criteria are amended so that projects delivering on the customer preferences receive a higher priority compared to other projects that the customer is less prepared to pay for.

- SH Maintenance Programme (asset preservation)
  Willingness to pay research is not as well developed for the asset preservation programme and implementation of customer expectations requires more careful consideration. Added to this are the many necessary interventions, such as crack sealing, resealing, etc, the need for which may not be perceived by the customer. In addition, a stated customer preference to achieve a high standard of ride on lowly trafficked roads may not be appropriate unless a willingness to pay can be demonstrated. Based on this it would then be necessary to assign economic benefits to some intervention activities required to meet customer preferences where there is currently no evaluation criteria. As Transit gains a better understanding of customer expectations it will cooperate with Transfund to eliminate any discrepancies that exist between national economic evaluation criteria and customer preferences and willingness to pay.
Asset Management

Aims Of Asset Management

In New Zealand Asset Management is seen as a process that provides the service expected for existing and future road users in the most cost effective manner. Transit aims to:

- Demonstrate responsible management of state highway assets by Transit on behalf of stakeholders.
- Provide a structured framework upon which Transit can improve its Asset Management practices.
- Provide a framework for road user consultation noting the relationship with road user expectation and asset preservation.

To provide this service Transit has developed an Asset Management (AM) Plan.

The Objective Of The Asset Management Plan

A key objective of Transit’s AM plan is to match the level of service provided by State Highway assets with the expectations of Road Users.

There are three key relationships:

1. The relationship between organisational, network and asset performance.
2. The relationship between service levels, intervention standards and technical standards.
3. The relationship between customer preferences and physical works on the road.

Recognising and understanding customer preferences is a key part of AM planning this relationship establishes the framework that will allow the development of service levels based on road user expectations, and the corresponding changes in AM practices.

Asset Management Complexities

The management of roading assets is complicated by the complexity of the nature of the assets and the environment in which they reside and must be maintained. Road pavements and surfacings are complex structures that do not perform or deteriorate in a scientifically predictable manner with performance being influenced by many factors. Complexities that result in the asset managers role being one requiring significant experience and taking on more of an artistic rather than scientific discipline include:

Consistency of Construction

The development process for most New Zealand roading assets has been evolutionary rather than designed or planned. Horse and foot tracks have been successively improved in an ad hock manner to cater for developing transport technology. As a result of this there is significant variability of construction from one kilometre to the next and in many cases very little engineering knowledge of the development.

Construction Materials

Materials used for the construction of the pavement and surfacing components are generally locally sourced. Many areas of New Zealand are geologically young and the local materials marginal in terms of their suitability in a load bearing structure. Many are moisture susceptible and very sensitive to loading changes. We are faced with the reality of having to retain these materials, applying experience to enhance their load bearing capability as they deteriorate and without the luxury of being able to replace them with ideal imported material towards the end of their life cycle.

Subgrade Variability

A principal determinant of the performance of a road pavement structure is the load bearing capacity of the subgrade on which it is developed. The strength of these subgrade materials is influenced by both the nature
of these materials, their insitu density and the moisture content of them. Subgrade properties can change many times in any kilometre of the network.

**Environmental**

The extent of environmental variability within New Zealand is significant. In particular, rainfall and temperature variability can vary significantly within small micro climatic regions. These environmental factors have a profound impact on the performance of roading assets.

**Traffic Loading**

Traffic loadings affect all aspects of pavement and surfacing performance. Measurement of the volumes of traffic, the axle loadings and configuration of vehicles does not yield absolute certainty and is an ongoing activity. Changes to traffic patterns is a variable that has a significant impact on road asset management.

An additional factor facing the roading engineer is the relatively low loadings on the majority of the New Zealand network. Low volumes affect the viability of parts of the network, the funding available for maintenance and result in deterioration being motivated principally by environmental influences rather than traffic loading.

**Deterioration Influences**

There are numerous dependent and independent variables that affect the performance of a pavement structure. Those mentioned above represent only a small sample of factors that must be understood to model and predict the performance of a roading asset.

**Linkage Between The Asset Management Plan And Other Documents**

Transit’s AM plan interacts with the following documents:

- **Statement of Intent:** A high level document with a medium to short term focus, which states Transit’s performance targets for the next three financial years. The output classes, performance measures and targets all link back to the strategies and plans in the National State Highway Strategy and ultimately to the Vision.
- **Corporate Plan:** The corporate plan is a new document produced to state the overall vision and objectives of Transit as an organisation.
- **National State Highway Strategy:** This is a key document which states Transit’s Long Term Mission, Goals and Objectives for the State Highway. All activities undertaken by Transit should work towards achieving the mission.
- **Transit/Transfund Service Agreement:** This is a legal document which states the services that Transit will provide to Transfund during the financial year and contains performance measures that Transit has agreed to achieve.
- **SH Programme:** This is a short-term document that compiles the programmes developed for a network maintenance management area and regional level for the forthcoming year. The AM plan states 10 year financial projections, forming the basis for the development of the annual plan.
- **Contracts, Network Management Proforma:** The service levels, strategies and information requirements contained in AM plans are translated into contract specifications and reporting requirements for operational and consultancy contracts.
- **Legislation:** The AM plan links with relevant legislation to demonstrate compliance with legislative requirements.
- **Bylaws, standards and policies:** These tools for asset creation and subsequent management are necessary to support AM strategies.
Key Issues In The Management Of State Highways

The key issues relating to the management of state highway (SH) assets are:

- **Pavements:**
  - Determining optimum intervention levels & minimum condition standards.
  - Implementation of predictive modelling.
  - Determining the impact of changing design standards.
  - Providing adequate drainage to minimise premature pavement failure.
  - Limited historical information about pavement structure and residual life.
  - Determining optimum rehabilitation cycles.

- **Bridges:**
  - Introducing a condition assessment methodology, which allows for predictive modelling.
  - Implementing an enhanced bridge management information system.
  - Prioritising bridge maintenance works.

- **Minor Structures:**
  - Development of more comprehensive risk management and condition assessment processes.
  - Reviewing the allocation of management responsibilities.
  - Improving completeness and accuracy of asset inventory.

- **Corridor Assets:**
  - Optimising intervention strategies.
  - Reviewing information needs to effectively manage corridor assets.
  - Developing improved materials and new products (new signs & markings).

- **Drainage:**
  - Improving the overall standard of surface drainage and culverts.
  - Improving knowledge of the scope, condition and performance of drainage assets.
  - Introducing a risk based approach for the lifecycle management of drainage assets.

Implementation Of The Asset Management Plan

Cost Effective Life Cycle

Cost effective life cycle management is resolving interventions to minimise the ownership costs over the full life of the asset. A conceptual life cycle model for a pavement asset is illustrated in figure 4. Cost effective life cycle management is the process of selecting the right maintenance treatments and applying them at the right time to minimise the area under the progressive (or accrued) facility maintenance cost curve.

Investment Criteria

Investment criteria applied to the expenditure of roading funds are based almost exclusively on economics. Within the framework established above:

- All service level criteria are tested against economics and must stand up to this scrutiny before adoption.
- Cost effective life cycle management is based on pure economics. The timing of treatments targeting minimising the net life cycle cost is established by testing economically the timing of options.
Inputs into the economic equation include:

- Capital and periodic or routine maintenance costs. Discounted cash low analysis is used to equate back to present costs. A ten percent discount factor is used for roading investment. The analysis period is typically 25 years for periodic and routine costs.
- Vehicle operating costs. Cover all aspects of the cost of operating vehicles on the network covering the effects of:
  - Travel time and distance (vehicle operating cost inputs, fuel, etc – and driver and occupant time costs)
  - Roughness. Accounts for the cost of operating a vehicle on rough surfaces.
  - Accident costs. Accounts for the cost associated with accidents and differentiates between property damage only accidents, minor injury accidents, serious injury accidents and fatalities. The costs associated with these are based on cost to the nation of lost productivity etc.

Economic analysis based on these inputs is either:

- Classical Benefit – Cost ratio (BCR) analysis. A ratio of the user benefits resulting from the execution of the work divided by the agency costs of achieving it. Projects competing for funds based on user benefit savings are ranked by BCR. At present a qualifying BCR of 4.0 is applied to all roading investment.
- Net Present Value. Used to validate projects where there are no user benefits but agency costs would be reduced by the application of investment. Typically used to test for the most cost effective maintenance solution. Is it more cost effective to carry out rehabilitation now to reduce maintenance costs, or should the intervention be deferred.

In general Benefit-Cost ratio analysis is applied to capital improvement projects where the incentive is reducing user costs, and Net Present Value to routine and preventive maintenance treatments.
Business Systems

Central to the delivery of services are the business systems designed to compliment the asset management methodologies described and the requirements outlined in the management systems. Key asset management business systems and their interrelationships are illustrated in the Figure 5.

Figure 5

The business system design recognises initially the key business functions being:
- Asset Management,
- Financial Management,
- Project Management,
- Funding Management, and
- Performance Management

The business information systems are illustrated in the figure within the key business functions that they service. The bracketed text gives the name of the specific information management system fulfilling the business need.

Treatment Intelligence

An information system that utilises the temporal (time based) condition data and the key inventory information and applies intelligence to this to assist in the decision making process.

Two methodologies are recognised:
**Probabilistic modelling.** Essentially experience based modelling where trends in condition data are matched against experience based outcomes. For example, experience tells us that it is necessary to consider correcting surfacing layer stability through a recycling process when:

- The condition information indicates that flushing is present,
- The life achieved from historic surfacing layers is decreasing,
- The number of surfacing layers present is greater than 5, and
- Condition data records the presence of shallow shear failure

Mathematical models developed within this framework usually follow the Markov principles of statistical analysis.

This treatment intelligence is sometimes referred to as the “experienced practitioner” or “grey haired gentleman” input. Reflecting on the complexities of roading asset management and the number of variables that influence deterioration the importance of this input is assigned a high value.

**Deterministic modelling.** A scientific process of applying scientifically based deterioration models to the condition data to predict condition change and intervention needs. The predictive modelling methodologies employed are discussed in detail in a subsequent section.

**Forward Works Programme**

The output from the treatment selection process is captured in a visionary forward works maintenance intervention programme. This programme records the predicted maintenance intervention needs for each treatment length on the network over a ten year programming period. The information system used to manage this process is called NOMAD (National Optimisation of Maintenance Allocation by Decade).

The programme recorded in the NOMAD application is regarded as dynamic and is regularly updated based on the observed performance of the network, the annual condition rating surveys and effectiveness monitoring of strategies applied under the programming philosophy.

**Maintenance Intervention Strategy**

Having committed a forward programme of intervention works it is necessary to communicate details and the intent of this to Contractors carrying out routine maintenance activities on the network. The normal maintenance activities will be significantly influenced by future commitments.

For example, if a pavement replacement is planned on a particular treatment length next year it is expected that the pavement will be deteriorating rapidly at present. Unless instructed otherwise the routine maintenance contractor will be very busy carrying out permanent repairs to maintain service level. In his example the maintenance intervention strategy would probably call for temporary repairs being carried out when safety is compromised. The service level will be reduced pending the replacement.

The Maintenance Intervention Strategy is an important communication tool linking the asset management engineer to the physical work resources.

**Annual Plan**

The Annual Plan is the compilation of the financial request to Transfund. It is drawn from the forward works programme and represents the financial needs for the current year required to support the ten year strategy on which the programme is based.

**Project Ranking And Justification**

A business process that recognises funding realities and the need to justify in detail some works (particularly those with a capital component where Benefit-Cost analysis is required) and rank others to enable pruning to meet funding constraints. The MARG information system provides for programme ranking to enable the application.
Funding Allocation Model

This is a business system that is operated by Transfund New Zealand. It is designed to provide an indicative estimation of the maintenance needs based on condition indicators, environmental considerations, the age profiles of assets in a particular area and other similar inputs. The output from this process provides a starting point for the funding agency to base its negotiations on.

Condition Achievement And Trend Analysis

Systems that monitor the change in condition of the network over time. Outputs include the key performance indicators that are used to audit the effectiveness of expenditure and achievement of contracted performance objectives. Trends in these indicators are used to calibrate treatment intelligence tools used in the first stage of the decision making process.

Deterioration Management

The treatment intelligence component of the business systems described is of particular interest and is described in more detail below.

Pavement Deterioration

The pavement portion of the roading asset is an elastic structure that deteriorates as a result of repeated load cycles. As the structure deteriorates it exhibits a number of fatigue symptoms that are measured as part of the annual condition rating surveys. These distress symptoms include:

- The development of wheel track rutting
- Increasing roughness
- Cracking
- The development of potholes
- The development of shallow shear failure

The onset and development of these symptoms can be modelled utilising equations that predict the rate of deterioration based on a complex matrix of factors that influence deterioration.

As the structure deteriorates the value of routine maintenance costs associated with correcting defects that compromise service levels increases. Again, equations modelling the development of these costs can be developed.

The figures below present a conceptual illustration of these two impacts of the deterioration of the pavement structure.
The predictive model contains mathematical models for a number of deterioration effects. Each include a decay curve and a trigger level (the minimum acceptable standard applicable to the condition being modelled at which time intervention is necessary).

**User costs**

Similar mathematical equations are developed representing the cost of operating vehicles under different levels of service. These models take into account the effect on vehicle operating costs of different levels of pavement roughness.
Work Effects

Each type of treatment will have a different effect on improvement on condition. Referring to the previous figure this improvement is termed a reset. At the point where the condition deteriorates to the trigger level the treatment is applied and the condition improved by the extent of the reset applicable to the particular treatment. Deterioration then re-starts from this reset condition value.

All treatment options available, the conditions that these are intended to correct, the reset in condition that will result from application of the treatment and the cost of the treatment are built into the Predictive Modelling equations.

Predictive modelling is a complex process of applying the pavement deterioration, user costs and work effects models to the existing pavement condition. The numerous matrix of potential treatment options and timings is evaluated using an economic model and recommended treatments, timings and terminal condition is output.

In very general terms, the process proceeds as follows:

1. Input each treatment length on the network
2. Input for each treatment length key descriptive data (structural capacity, dimensions etc)
3. Input condition data for each treatment length (rut depth, roughness, cracking extent etc)
4. Input traffic volume data
5. Deterioration model predicts the change in condition that will occur over time outputting a predicted condition for each year
6. User cost model calculates the vehicle operating costs associated with using the asset in the condition predicted
7. At any time when the trigger level is reached for any of the condition inputs each treatment that will address the particular condition is applied
8. Economic analysis is applied to select the most appropriate treatment from those tested
9. Condition is reset according to the reset value assigned to the selected treatment
10. Deterioration model predicts the change in condition from this reset value that will occur over subsequent years
11. The process continues to the end of the analysis period

This process can be illustrated as in Figure 8.

Figure 8. Predictive Modelling Process
Project Selection

Project selection is often determined by using the total transport cost option. This looks for the lowest total cost option from a combination of user and agency costs. As can be seen in the figure the plot of this total cost is represented by a sag curve. The most cost-effective option is at the lowest point on this curve.

Figure 9. Total Transport Cost Model

Outputs

There are numerous output possibilities from the predictive modelling methodology. Obviously the key output is the schedule of recommended treatments for each treatment length for all years over the analysis period. These are generally output into a table for field verification prior to inclusion in the forward works programme.

The process can also output many different illustrations of the impacts of the selected programme on the performance of the network. Two are provided to illustrate this. Figure 10 illustrates the predicted change in the overall condition over time resulting from the application of a particular budget constrained programme whilst Figure 11 illustrates the predicted change for different budget options.
The Future

The overall quality of Transit road management practice has been assessed by expert Asset Management consultants as equivalent to international best practice.

The majority of the asset management business practices are clearly identified and structured in the manuals that compliment Transit’s formal business systems. Overall the current standard of Transit’s AM practices are high, and the financial projections are supported by well documented processes, strong data-bases and suitable information systems. The degree of compliance with the documented processes is very high.

Transit has a strategy of continuously improving AM processes, systems and data to achieve its Vision to be ‘A World Leader in Roading Solutions’. The improvement tasks identified in this plan focus on:

- Reviewing and development processes to support advanced asset management concepts (risk assessment, deterioration modelling, optimised decision making and service level review).
- Implementing an on-going programme of road user consultation to review adopted levels of service.
- Improving processes for maintaining as-built plans and data management.
- Reviewing contracting policies and procedures.
- Reviewing intervention strategies for asset maintenance

Acknowledgements:
The presenter wishes to acknowledge the many contributors from Transit New Zealand for this lecture series notably Graham Taylor, Gordon Hart, Dave Robertson, Chris Shepherd and John Donarvand.
A Framework for Road Asset Management

Introduction

Asset value
Roads in all countries represent an important national asset. For many countries, the asset value will be comparable with that of some of the world’s largest companies. For example, in the United Kingdom, the value of the asset managed by the Highways Agency is comparable with that of IBM; the Japan Road Public Corporation manages assets roughly equal to those of General Motors (Heggie and Vickers 1998). Management of a road network asset of such a value requires adoption of the most careful management practices commensurate with those adopted by the most successful businesses.

Management framework
Management, by its nature, is not a subject that follows normal scientific or engineering principles. It is more of an ‘art’ than a ‘science’. Rather than to try and seek a technical theory on which road management decisions can be based, there is a need to adopt a ‘framework’ for management. Such a framework enables management decisions to be made in a structured manner that is logical and consistent. It can provide guidance on the type of decisions that must be made, the purpose of those decisions, who needs to make them, when they must be made, the information needed to make the decisions, and on other aspects. It can assist in improving the quality of decision-making, and result in greater effectiveness and efficiency for both customers of the road network and the road administration.

The management cycle

Background
Various attempts have been made in the United Kingdom in recent years to improve the way that roads were managed. Key initiatives were the Marshall (1970) Report, which provided the first rational basis for identifying maintenance needs. The original Local Authorities’ Code of good practice was perhaps the first to put forward the concept of a ‘management framework’. In his paper describing the background to its introduction, Madelin (1984) describes how the code was developed to encourage highway administrations in local government to adopt a systematic approach to decision-making, to provide greater consistency between administrations, to improve the effectiveness of resource allocation, and to provide the basis for policy review.

Recent initiatives
The Code was updated by the Local Authority Associations (1989) to reflect experience of use of the first edition. Since then, there have been various other initiatives in this area including, more recently, ‘benchmarking’ (Meszaros and Owen 1997) and ‘best value’ (DETR 1998). Currently, some authorities are considering applying the principles of ‘asset management planning’ from other infrastructure sectors to draw on this wider experience (Robinson and Ford 1999). However, the 1989 Code still underpins the management framework adopted by most road administrations, and is currently being updated.

An existing management model
The basis of management put forward in the 1989 Code is shown in Figure 2.1. This recognises that management of the road network can be carried out as a structured series of steps in a cyclic manner. The process illustrated will be recognised as the ‘management cycle’ for decision making from business management theory.

Programming
Consideration of Figure 2.1 more carefully reveals that the process being modelled is that for the preparation of an annual programme of works which can be funded from the available budget. The cycle also covers the implementation of works, and the monitoring of results to enable aims set in the following year to ‘learn’ from the experience of the previous year’s activities. This emphasis reflects concerns of highway managers at the time when the focus was on day-to-day pressures of how best to allocate this year’s budget. However, pressures now require that a more strategic view is taken of highway
management. The development process behind the United Kingdom Pavement Management System (Phillips 1994) demonstrated conclusively the benefits to be obtained by taking a life cycle approach to budget prioritisation. The ‘best value’ initiative and ‘asset management planning’ both require that a longer term perspective of decision-making is taken. The requirement to produce local transport plans (DETR 1999) also requires such a perspective. It is perhaps now time to move on and to adopt a management framework that encompasses these needs.

Figure 2.1. Management model proposed in the LAA highway maintenance code of good practice
(Adapted from: Local Authority Associations 1989)

Different decision cycles
Preparation of an annual programme of works is sometimes referred to as ‘programming’. However, decisions also have to be made in other areas of management. The different types of decision have cycles of different durations. For example: ‘strategic planning’ relates to time periods of several years; design work and the letting of contracts are carried out normally over periods of much less than one year; the management of on-going works involves taking decisions over cycles with relatively short durations, perhaps lasting for a few weeks or even a few days. Recognition of the various types of decision related to managing road networks suggests that a framework for road management could be adopted which encompasses a wider range of decision types than has been normally considered.
Generic management cycle
A management cycle of a more generic nature than that described above can be used to make any management decision relating to roads. The duration of the cycle will depend on the type of decision being made, as noted above. Such a cycle can be considered in terms of the following six steps.

i) Define aims
The policy framework of the administration defines its aims for road management. Defining the goal being sought is an essential first step in the management cycle for each area of decision making, since all activities must be undertaken with a view to meeting defined aims.

ii) Assess needs
The key step in assessing needs is the collection of data. These data provide information on the extent of the gap between the present level of service or standard and that required to meet the defined aim, as defined above. This, in turn, permits identification of the activities that are required.

iii) Determine actions
There will often be choices to be made about the activities required to meet the aims identified by the above. Alternatives must be considered to determine the most appropriate options.

iv) Determine costs and priorities
Actions identified above must be costed to identify the resource requirements. Resource needs identified will normally be greater than those available to carry out the required activities. A rational system of setting priorities is therefore required to allocate available resources in a systematic and equitable way, such that the best value for money is obtained.

v) Implement activities
This involves all activities undertaken during execution of the decision. Implementation must ensure that activities are carried out to predefined standards in order that the administration’s aims are met.

vi) Monitoring and audit
A review process must form an integral part of needs-based road management. This process should include the following two activities:
   a) Monitoring
   has the principal function of providing feedback to the management process, so that when the next cycle of management takes place, it can learn from past experience; for example: aims can be redefined to reflect the actual achievements; unit rates can be revised to reflect those actually obtained in undertaking the work; or, indeed, technical methods may be improved on the basis of the monitoring
   b) Audit
   this includes both technical and financial audit, and provides a physical check, usually on a sample basis, that implementation has been carried out to pre-defined standards or procedures, and that costs and other resources have been accounted for properly

Management functions
Definition of functions
Areas where the management decisions have to be made can be considered as ‘management functions’. It has been found to be convenient to define these functions (Kerali and others 1998, Robinson and others 1998) under the four headings of:

   a) Strategic planning
   b) Programming
   c) Preparation
   d) Operations
Dimensions of management decisions

The four functions differ in their aims, in the time horizon of the management decision, the extent of the road network which is considered, and the staff who are concerned with the result. The time, spatial and staff dimensions related to each management aim are elaborated in Table 3.1.

Table 3.1. Road management functions, aims and dimensions

<table>
<thead>
<tr>
<th>Management functions</th>
<th>Strategic planning</th>
<th>Programming</th>
<th>Preparation</th>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical management aims</td>
<td>a) Determining optimum road standards</td>
<td>Determining work programme that can be carried out with next year’s budget</td>
<td>a) Design of works b) Preparation and issue of contract or work instruction</td>
<td>Undertake tasks as part of works activity</td>
</tr>
<tr>
<td>b) Determining budget required to support given standards</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time horizon dimension</td>
<td>Long term (strategic)</td>
<td>Medium term (tactical)</td>
<td>Budget year</td>
<td>On-going/ immediate</td>
</tr>
<tr>
<td>Spatial coverage dimension</td>
<td>Whole network</td>
<td>Sub-network of sections likely to need treatment</td>
<td>Sections of road made up into contracts or work packages</td>
<td>Sub-sections where works are currently taking place</td>
</tr>
<tr>
<td>Staff dimension</td>
<td>Results of interest to senior managers and policy makers</td>
<td>Managers and budget holders</td>
<td>Engineers, technical and contracts staff</td>
<td>Works supervisors</td>
</tr>
</tbody>
</table>

Decision making for management functions

The management cycle can be used as the basis of taking decisions for each of the management functions. For example, the management cycle for strategic planning might be as shown in Figure 3.1.

![Figure 3.1. Example of a management cycle for strategic planning](image-url)
Dimensions of management

Management processes for different functions

Change in the management processes
As the management process moves from strategic planning through to operations, it will be seen from Table 3.1 that the following changes occur:

a) The time horizon considered changes from multi-year to budget year, and then to the current week or day 
b) The road sections considered change from all sections in the network to only those sub-sections where works are likely to be carried out 
c) The key management staff concerned change and become less senior 

Other dimensions of management
This framework of definitions in terms of strategic planning, programming, preparation and operations, also provides a rational basis for other aspects of road management, including the following:

a) Detail of the description of the road works carried out 
b) Definition of the road organisation’s policy framework 
c) Data definition 
d) Methods of costing used in road management 
e) Other dimensions, including the ease of contracting out, and the type of computer systems used to support the management function 

These are considered below.

Road works

Categorisation of road works
The Code of good practice categorises road works as in Figure 4.1. This reflects traditional thinking about the different types of works and their relationship to each another. It appears to mix together descriptions of the works (such as ‘cyclic maintenance’) and descriptions of the assets themselves (such as ‘aids to movement’ and ‘street lighting’).

Asset management classification
An alternative way to describe the different activities is to adopt terminology from the discipline of ‘asset management’ (National Asset Management Steering Group 1996). There is an increasing realisation that highways can be considered as part of a more general infrastructure asset that can be managed and monitored on a similar basis using common procedures. Increasingly, in many countries, the discipline of asset management is providing a common framework and language of communication between operators, contractors, government departments, regulators, economists and politicians with an interest in infrastructure. Asset management practice uses the terms maintenance, operations, renewal, development and disposal to define the different types of activities on an asset. These terms can be used irrespective of the type of asset being managed. Table 4.1 provides a grouping of carriageway and shoulder works using asset management terminology.

Other features
Similar groupings of works could be given for the maintenance of other features, such as bridges and structures, footways and cycle tracks, street lighting, road signs and furniture, and the like.
Tasks

Activities in Table 4.1 can be broken down into ‘tasks’ for the purposes of operational costing and management. For example, surface dressing might be broken down into the tasks of:

1) Place signs and traffic control devices
2) Prepare existing surface and carry out any pre-patching
3) Ensure surface is clean and free from loose material by brushing
4) Mask surface iron work
5) Apply bituminous binder

6) Apply chippings

7) Roll

8) Re-expose iron work by removal of masking

9) Apply lines and markings

10) Remove signs and traffic control devices

**Relationship to management functions**

The benefit of adopting this approach is that works ‘categories’ for different highway features are broken down into successive levels of detail which, in Table 4.1, are termed ‘types’, ‘activities’ and ‘tasks’. There is merit in considering the description of works in this way because, as the management function changes from **strategic planning** through to **operations**, works need to be defined in more and more detail. For example: when carrying out **strategic planning**, decisions need only relate to broad ‘categories’, such as whether works are of a ‘routine’ or ‘periodic’ nature; for the **preparation** of designs and contracts, more detail is needed, perhaps to enable ‘activities’ to be included in a bill of quantities. Thus, in general terms, the level of detail at which it is appropriate to define road works can be related to the four management functions in the following way:

- a) Works category: **strategic planning**
- b) Works type: **programming**
- c) Activities: **preparation**
- d) Tasks: **operations**

However, it is recognised that, although this provides a useful concept or framework, there will be many grey areas where the relationship between works definition and management function will not be clear cut.

**Inspections**

Highway management in the United Kingdom places great emphasis on inspections. These assist in identifying needs. They should be scheduled in a way that enables statutory requirements to be met, and to provide a cost-effective basis for determining work requirements. Thus, inspections provide a means-to-an-end; they should not be confused with actually undertaking work on the road. However, there will be some situations where it is efficient to combine inspections with works execution.

**Policy framework**

**Policy aims**

**Purpose and structure**

A policy framework provides the context within which decisions can be taken about funding and all other aspects of road management. Road management functions should provide a mechanism for implementing the policy framework of the road administration. The policy framework sets out the administration’s overall goals, and how achievement of these will be measured. One approach is to set policy at three levels (Robinson and others 1998):

- a) Mission statement
- b) Objectives
- c) Standards

A **mission statement** outlines, in broad terms, the nature of the operation being managed by the organisation which has responsibility for the road network. The mission is formulated at a relatively high level, and is normally kept fairly brief, since it is targeted at senior policy makers and politicians. For a road administration, organisational missions provide a high level statement of sub-sector policy, and have the purpose of allowing differentiation and comparison of institutional roles and policies between different sectors and sub-sectors.
They also provides a broad concept to inspire individuals in the organisation, and to enable them to see how their own contribution fits into its wider aims.

### Table 4.1. Grouping of carriageway and shoulder works

<table>
<thead>
<tr>
<th>Works group and category</th>
<th>Works type</th>
<th>Examples of activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Routine planned</td>
<td>Cyclic</td>
<td>• Sweeping</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Vegetation control</td>
</tr>
<tr>
<td>• Routine unplanned</td>
<td>Reactive</td>
<td>• Patching</td>
</tr>
<tr>
<td></td>
<td>Winter</td>
<td>• Salting/gritting</td>
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<tr>
<td></td>
<td></td>
<td>• Snow removal</td>
</tr>
<tr>
<td></td>
<td>Emergency</td>
<td>• Traffic accident removal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Landslip removal</td>
</tr>
<tr>
<td>• Periodic (planned)</td>
<td>Preventive</td>
<td>• Fog seal</td>
</tr>
<tr>
<td></td>
<td>Resurfacing</td>
<td>• Single surface dressing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Porous asphalt overlay</td>
</tr>
<tr>
<td>Operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Administration</td>
<td></td>
<td>• Finance and accounts</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Personnel management</td>
</tr>
<tr>
<td>Facilities management</td>
<td></td>
<td>• Toll collection</td>
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<tr>
<td></td>
<td></td>
<td>• Maintenance of depots</td>
</tr>
<tr>
<td>Policing</td>
<td></td>
<td>• Speed enforcement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Axle load control</td>
</tr>
<tr>
<td>Renewal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overlay</td>
<td></td>
<td>• Dense-graded asphalt overlay</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Bonded concrete overlay</td>
</tr>
<tr>
<td>Pavement reconstruction</td>
<td></td>
<td>• Mill and replace</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Inlay</td>
</tr>
<tr>
<td>Development</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Widening</td>
<td></td>
<td>• Lane addition</td>
</tr>
<tr>
<td>Realignment</td>
<td></td>
<td>• Local geometric improvement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Junction improvement</td>
</tr>
<tr>
<td>New section</td>
<td></td>
<td>• Dualling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• By-pass construction</td>
</tr>
<tr>
<td>Disposal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Asset disposal</td>
<td></td>
<td>Asset disposal is seldom used in connection with carriageways and shoulders except in a few cases of ‘de-gazetting’</td>
</tr>
</tbody>
</table>

*Objectives* set specific goals to be achieved within the short to medium term (tactical) and long term (strategic) time scales. Each item in the mission statement should be supported by one or more objectives. Objectives are usually targeted at the professional engineers and managers in the organisation who have the responsibility for delivering results in the form of work programmes. Often these will be the budget holders in the organisation. Objectives enable these results to be quantified in a way that enables achievement to be measured.
Standards provide the detailed operational targets to be worked to by individuals in the organisation. Each objective should be supported by one or more standards. These provide detailed operational targets to be met on a day-to-day basis. They are normally targeted at technicians, inspectors, and other sub-professionals, who have responsibility for ensuring that policy is implemented on the ground.

Framework for decision making
All standards should support an objective, and all objectives should be reflected in the mission statement. The mission statement, objectives and standards thus provide a consistent set of criteria that can guide all decisions.

Customer interests
Customer groups
It is important for a road administration to appreciate and understand that there are customers for all aspects of its work. The main customers are the road users, who include:

a) Owners and operators of commercial vehicles and buses
b) Representatives of industry and commerce who have a vested interest in an efficient road network to support their business operations
c) The travelling public using the road network

In addition to customers or users, there are other ‘stakeholders’ in the network. These include the road administrations themselves, and the road engineering industry. Road administrations are funded by the tax payer, so it is important that their services are related to the needs of the tax payer, as expressed by government, local politicians and others. Contractors and consultants will be stakeholders where they have an interest in participating in the planning, design and execution of works, and in the management of the network.

Target audience for policy framework
One particular reason for separating the policy framework into three levels is that each is applicable to a different customer, audience or vested interest. The internal customer interests, along with the relationship between the levels of the policy framework, are shown in Figure 4.2. The policy framework is also a useful tool for informing external customers of road network needs and of the road administration’s aims relating to these. This is normally done by publishing mission statements, and ‘performance indicators’ relating to key objectives from the policy framework. Wide publication helps to generate interest and awareness of issues, and to engender support from both elected representatives and the public.

![Figure 4.2. Relationship between components of the policy framework and vested interests](Source: Robinson and others 1998)
Relationship to management functions
From this, it will be seen that there is a relationship between the components of the policy framework and the four management functions.

a) Mission statement: strategic planning
This is concerned with overall aims, and considers the whole road network. The main customers for the mission statement and strategic plan are senior policy makers. The purpose of the strategic plan can be considered to be delivering the mission statement of the organisation.

b) Objectives: programming
This is concerned with determining specific outputs to be provided, and relates to that part of the network which is to be the recipient of the budget. Its customers are the professionals in the organisation who are budget holders. The purpose of programming is to determine the work necessary to deliver the objectives of the organisation.

c) Standards: preparation and operations
These are concerned with individual projects and works, and are related to specific sections of road in the network. Their main customers are professionals and technicians. Preparation and operations are concerned with meeting the standards from the policy framework.

Information requirements

Changing requirements for information detail
Management decisions need to be based on information if they are to be effective. Thus, ‘information’ sits at the heart of the management cycle, as shown in Figures 2.1 and 3.1. Information is the combination of data, its processing, and its dissemination. It can be seen that, as the management process moves from strategic planning, through programming and preparation, to operations, the amount of information required to assist with management decision-making increases progressively in intensity, but reduces in the extent of its network coverage. Determining the appropriate information detail required will depend on the management function for which it will be used.

Information quality
The World Bank has devised a rigorous basis for classifying information needs in its guidelines on information systems (Paterson and Scullion 1990). This proposes the concept of information quality levels (IQL):

(a) **IQL-I**
Most detailed and comprehensive level of data. Collected on short to limited lengths of road, or isolated samples, using specialised equipment. Data collection is slow except when using advanced automation.

(b) **IQL-II**
Detailed data. Collected on limited lengths of road using semi-automated methods; or full network coverage using advanced automation at high speed.

(c) **IQL-III**
Summary data with categorisation of values. Collected on the full network using high-speed, low accuracy semi-automated methods; or on a sample basis at slow speed. Alternatively, information can be obtained by processing other data.

(d) **IQL-IV**
Most summary data. Collected manually, or using semi-automated methods. Alternatively, information can be processed or estimated.

Information groups
In the World Bank guidelines, detailed recommendations are given for appropriate data to collect for each information quality level for the following ‘information groups’:

(a) **Road inventory**
Network/location, geometry, furniture/appurtenances, environs

(b) Traffic
Volume, loadings, accidents

(c) Pavement
Pavement structure and condition

(d) Structures
Structures inventory and condition

(e) Finance
Costs, budget, revenue

(f) Activities
Projects, interventions/treatments, commitments

(g) Resources
Personnel, materials, equipment

Relationship to management functions
Considered in simple terms, the relationship between management functions and appropriate information quality level can be assumed to be the following:

a) IQL-IV: strategic planning
b) IQL-III/IV: programming
c) IQL-II/III: preparation
d) IQL-I/II: operations

The actual level will depend, amongst other things, on whether the management decision is concerned with major or minor roads. Thus, by referring to the World Bank guidelines, appropriate and cost-effective levels of data can be collected and used when undertaking each of the four management functions.

Methods of costing

Appropriate cost estimation methods
At all stages in the management process, it is necessary to estimate the cost of works. As the process moves from strategic planning through to operations, the cost information needs to increase both in its level detail and its accuracy, if its use is to be cost-effective. Three different types of costs are available (UMIST Project Management Group 1989).

a) Global costs
‘Broad brush’ costs related to the overall size or capacity of the works or activity; eg cost per kilometre of road.

b) Unit rates
Bill of quantity approach to costing; eg cost per cubic metre of material.

c) Operational costs
Costs built up from fundamental units of equipment, personnel and materials needed to complete work as defined in a method statement.

Relationship to management functions
The different costing methods have different requirements in terms of data detail needed for cost estimation, of the accuracy and tolerances appropriate, and of the cost per unit of data collection. Clearly, different costing methods are appropriate to the different management functions.

a) Global: strategic planning
b) Unit rate: programming, preparation
c) Operational: operations
Contracting out

Other dimensions of management also change as the management process changes from strategic planning through to operations. For example, the management role changes from that traditionally identified as a client function to that which is increasingly easy to contract out.

Specification of systems

Various types of computer-based decision-support systems are currently available, and are marketed as ‘maintenance management systems’, ‘pavement management systems’, ‘inventory management systems’, and the like. The use of these terms has sometimes caused confusion. For example, pavement management systems produced by different vendors can have quite different characteristics (Robinson and May 1997). Classifying systems according to the management function addressed by their application overcomes this problem, as shown below:

(a) *Strategic planning systems*
System for strategic analysis, network planning, pavement management (some aspects)

(b) *Programming systems*
System for programme analysis, pavement management (some aspects), budgeting

(c) *Preparation systems*
System for project analysis, pavement management (some aspects), bridge management, pavement/overlay design, procurement and contract management

(d) *Operations systems*
System for project/contract management, maintenance management, equipment management, financial management/accounting

System specification

Adopting this terminology for systems facilitates their specification in the following way:

a) The main purpose of objective of the system can be defined in terms of one of the management functions, as in Table 3.1

b) Potential users of the system can be determined from the staff dimension, also in Table 3.1

c) Data design for the system can be undertaken on the basis of information quality levels, depending on the system type as defined above

Computer processing

As the management function being supported by computer system moves from strategic planning through to operations, computer processes change from being automatic, with standard or pre-defined reports being produced on a regular basis, to being undertaken by the manager working interactively with the computer.

The management framework

*Components of the management framework*

The paper has introduced a framework for road management that is based on the four management functions of strategic planning, programming, preparation and operations. The framework has been discussed from the point of view of different ‘dimensions’ of management, and this has suggested that the approach provides a rational basis for considering several aspects of the road management process which is more comprehensive than that currently included in the LAA Code of good practice. The four management functions provide a framework that links together:

a) The time frame to which the decisions apply, which varies from long term (strategic) to immediate

b) The road system being considered, in terms of its spatial coverage, varying from the entire network to detailed sub-sections

c) Staff interested in the decision, in terms of their seniority
d) The detailed manner in which road works are defined

e) Definition of the road administration’s policy framework by recognising that
   - there is a different audience for each of the management functions
   - the mission statement, objectives and standards each relate to different management functions

f) Data definition, by linking requirements for information quality levels to the different management functions

g) Methods of costing used in road management, whereby the need to use global, unit rate or operational costing methods varies depending on the management function

h) The ease of contracting out

i) Automatic or interactive computer systems to support the decision making process depending on the management function

Summary of management framework

Given these considerations, it is now possible to extend the concepts first introduced in Table 3.1 to a number of related areas of road management, as shown in Table 5.1. It will be seen from this table that consideration of the road management process in terms of four primary functions provides a rational, logical and consistent framework for decision making covering a number of dimensions of management.

Management functions and cycles

Decision-making within each management function can be undertaken using the management cycle, such as the example in Figure 3.1. The combination of management functions and management cycles can be characterised as in Figure 5.1 to provide a new framework for road management.

Practical application

This is not just a theoretical concept: it has real practical application in the day-to-day management of road networks. It can provide a basis for clarifying responsibilities for different types of decision, and can assist in formulating policies that are more coherent and integrated. It links together planning frameworks over short and long term time horizons. Above all, it provides a basis for the way that managers use information, whether that be information about the detail in which works are defined, the type of costing method to use, or the quality of data to be collected and stored. Information is at the heart of all management decisions. It is expensive to assemble and to store. The management framework put forward offers a means of making more cost-effective use of information, improving the quality of decisions, be they short term or strategic.

Strategic approach

Application of these concepts to highway management provides a framework for taking a more strategic approach to decision making. Such an approach is necessary for the achievement of ‘best value’ and for the development of ‘local transport plans’. More fundamentally, a strategic approach is crucial for those who have to manage highway networks in a context of rising public expectations and decreasing resources.

Acknowledgements

Many people have contributed to the development of the ideas in this paper. In particular, I would like to acknowledge the assistance of Mr Uno Danielson of the Swedish National Road Administration, and Professors Martin Snaith and Keith Madelin of the University of Birmingham School of Civil Engineering. I am also grateful to the Local Government Association for permission to use illustrations based on the those in the Local Authority Associations’ Highway maintenance: code of good practice.
Table 5.1 The road management framework

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Management functions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strategic planning</td>
</tr>
<tr>
<td>Time horizon</td>
<td>Long term (strategic)</td>
</tr>
<tr>
<td>Spatial coverage</td>
<td>Whole network</td>
</tr>
<tr>
<td>Staff concerned</td>
<td>Results of interest to senior managers and policy makers</td>
</tr>
<tr>
<td>Road works definition</td>
<td>Works categories</td>
</tr>
<tr>
<td>Application of policy framework</td>
<td>Mission statement</td>
</tr>
<tr>
<td>Information quality level</td>
<td>IQL-IV</td>
</tr>
<tr>
<td>Methods of costing</td>
<td>Global</td>
</tr>
<tr>
<td>Ease of contracting out</td>
<td>Relatively difficult</td>
</tr>
<tr>
<td>Computer processing</td>
<td>Automatic</td>
</tr>
</tbody>
</table>

Figure 5.1 Framework for road management showing functions and cycles
References


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Richard Robinson
Examples of benefits from the application of policy frameworks


Routine maintenance

“Because some authorities have no clearly defined policies and do not know what they are trying to achieve, they are over-providing services, paying too much for work, cannot be certain that the work they pay for has been carried out adequately (or at all) - and do not know what they are achieving for the money they spend. Better specification of services, full inventories, improved budgeting, supervision and monitoring, and more competitive tendering are needed to secure value for money.”

<table>
<thead>
<tr>
<th>Case Study 1: Review of routine maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road administration</td>
</tr>
<tr>
<td>Subject</td>
</tr>
<tr>
<td>Problem:</td>
</tr>
<tr>
<td>Action:</td>
</tr>
<tr>
<td>Outcome:</td>
</tr>
</tbody>
</table>

Gully emptying

“There is evidence......that the recommended frequencies for gully emptying in the codes do not necessarily apply to all gullies. While some may need emptying six times a year, others do not need emptying for two or three years or even longer. Auditors have found significant bonus over-claims from operatives who themselves have assessed and applied the needed frequency of emptying while claiming the higher policy frequency.”

Benefits of road inventory

“Inventories are not compiled simply for reasons of bureaucratic tidiness. They can bring real benefits. One authority discovered that it had be under-recording its road length and thus losing central government block grant. The same authority claims a 20 per cent improvement in gully emptying efficiency since it gave plans of routes and gully locations to drivers. Another authority made savings of between 9 and 61 percent on various routine maintenance functions once it had collected inventory data and formalised its budgeting.”

<table>
<thead>
<tr>
<th>Case Study 2: More systematic approach to routine maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road administration</td>
</tr>
<tr>
<td>Subject</td>
</tr>
<tr>
<td>Problem:</td>
</tr>
<tr>
<td>Action:</td>
</tr>
<tr>
<td>Outcome:</td>
</tr>
</tbody>
</table>
“Accurate and up-to-date inventories are particularly important for street light maintenance. Street lights normally use un-metered electricity and bills are calculated using a price per installation. This varies with the overall wattage of the lamp plus its associated control gear, and whether the lamp is alight for part or all of the night. In many cases, electricity boards use their own inventories rather than details held or provided by the road authority. Comparison often reveals discrepancies. Some favour the local authority (for example, where the board has not picked up a road adoption); others favour the board (where, for example, it has not taken account of conversions to lower wattage, more energy efficient lamps). Some authorities were substantially over-charged. One has identified over-payments of £125 000 (approx $200 000) a year; another has negotiated repayment of over-charges.

**Case Study 3: Over-payment for electricity**

<table>
<thead>
<tr>
<th>Road administration</th>
<th>A county council</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>Checking of street lighting energy accounts</td>
</tr>
<tr>
<td>Problem:</td>
<td>The electricity board invoiced the county council based on historical information about the number of lamps, the type of lamps and switch-gear, and the burning regime (all night or part-night lighting). The county council paid the invoices as rendered because they had no better information with which to check them.</td>
</tr>
<tr>
<td>Action:</td>
<td>Street lighting maintenance for the county’s directly-controlled lighting was put out to open tender and the successful tenderer was required to collect full inventory information as part of the contract. This inventory was then compared with the electricity board charging schedules.</td>
</tr>
<tr>
<td>Outcome:</td>
<td>The total number of lamps being charged for was 9 800 more than remained in service. The types of lamp being charged were at variance with those in service, and conversions to energy-efficient lamps had not been reflected in the invoices. The authority negotiated a repayment from the electricity board, and there are on-going annual savings of £125 000 (approx $200 000).</td>
</tr>
</tbody>
</table>

**Explicit policies**

“Local highway authority members should see it as their prime responsibility to formulate policies on road maintenance, taking into account the local circumstances and the published codes. Counties should consult all their districts before formulating policies, but then ensure that their agents are adhering to their policies within the discretion granted. Firstly, members should initiate a review of the frequency of routine maintenance to see whether scope exists for reducing the frequency of some activities. In some authorities the scope may be limited, but every authority should examine its frequencies critically and test the effect of reductions by, for example, a pilot trial in one particular area. Members should also ask engineers to review the intervention levels for periodic maintenance.”

**Reference:**